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The political reception of innovations

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Abstract

Why do some societies embrace innovative technologies, policies, and ideas, while others are slow to adopt, and some even resist, them? Incumbent producers are most likely to be affected by certain kinds of innovations; they also wield a disproportionate influence in the design of institutions and policies that encourage or limit their adoption. We show formally that the elite has four cardinal policy options: to appropriate the innovation for itself; to encourage its adoption; to tax, regulate, or limit the innovation; or to block it. We show that six features of an innovation determine how it is received: (i) whether it is easy to replicate; (ii) whether it complements or competes with the elite's sources of income; (iii) whether its impact is broad or narrow; (iv) whether it is location-dependent, and (v) concealable; (vi) whether it requires large fixed costs. While other works have occasionally considered one of these factors, we show where each feature comes from, and we assess them systematically and together. We provide illustrative evidence of the relevance and generality of the model to understand the fate of a variety of innovations.

KEYWORDS

innovation, non-market strategies, regulation, rent-seeking

1 | INTRODUCTION

Innovation is central to growth and development. An incumbent elite may, however, regard innovative activity as a threat to the existing social structure, or to the distribution of political power (Acemoglu & Robinson, 2000; Juma, 2016; Mokyr, 2016; Solstad, 2020). Many accounts of the stagnation or decline of societies include as a major cause reluctance about or opposition to innovative ideas and techniques (Allen, 2009; Deaton, 2013; Hoffman, 2015; MacMullen, 1988; Parente & Prescott, 1994; Rosenberg & Birdzell, 1986; Rosenthal & Wong, 2011; Stasavage, 2014).

Vested interests may also oppose specific innovations that they believe threaten their livelihood. These innovations may be technological, such as the introduction of new means of production. They may be organizational, such as new ways of structuring economic activity. They may be governmental, such as a transformation of regulatory or macroeconomic policies. The innovations may be developed within the society itself, or adopted and adapted from advances made in other societies. Those who resist innovation are often considered "Luddites," after the English textile-workers who protested—and sometimes destroyed machinery—in the early 19th century. This is probably misleading, as the protests were usually more about wages and hours than machinery itself. Yet, although new organizational forms, technologies, discoveries, and policies may be at the core of social progress, they may also threaten the order on which elite wealth is founded. Even yesterday's innovators may become today's opponents to an innovation that threatens their newly entrenched interests (Mokyr, 1994).

This paper analyzes how the nature of particular innovations affects the incentives for an incumbent elite to encourage or limit their adoption. We consider an incumbent elite faced with two potentially conflicting objectives: to protect or enhance the return on its assets, and to maximize tax revenue that it can appropriate.[1] We characterize the first as factor-price manipulation, and the second as revenue maximization. For the former, the elite would encourage an innovation that complements its own sources of income and limit or block a rival innovation. For the latter, the elite would consider the innovation's susceptibility to taxation and incentive-effect (cf. Laffer curve) constraints on taxation. The main policy tools affect both tax revenue and the income-yielding property of the elite's assets. Taxation of the innovation, for instance, yields tax revenue for the elite. It also affects how extensively the innovation is applied, and the externality it may have on the elite's existing activities. With a positive externality (a complementary innovation), the elite may choose a lower tax rate to increase the yield on its existing assets, even though it may reduce the revenue from taxation. With a negative externality (a rival innovation), the elite may prefer a higher tax rate, even though this may reduce the revenue it receives from taxation.

We analyze this trade-off by giving members of the elite control of fiscal policy and regulation, and the potential opportunity to control the innovation and exploit it themselves. More precisely, the elite sets and collects taxes, sets and regulates entry, and decides whether to apply the innovation itself. In this context, the elite's preferred policies are affected by features of the innovation that can affect the viability and potency of particular policy instruments.

Our setup reveals features of an innovation that matter for how an incumbent elite that controls government policy is expected to respond to the innovation. The elite might appropriate the innovation itself, tax the supply of the innovation, and regulate or deregulate entry intro supplying the innovation. Our analysis reveals four cardinal policies that the elite may choose to implement, depending on the features of the innovation. The elite might

1. Appropriate the innovation itself (or compromise to share rents with the innovators), regulate entry into supplying the innovation, and earn the rents attaching to it. This depends on the incumbent elite being technically or otherwise able to appropriate the innovation.
2. Allow others to implement the innovation and tax the resulting rents to redistribute them to itself. It would then encourage (deregulate) entry to compete away some or all of the innovation-driven rents. This is attractive if the elite cannot, or prefers not to, take over the innovation itself.
3. Block the innovation. This could be achieved by high enough levels of taxation, for instance. This is attractive for an innovation undesirable to the elite, even if that innovation would bring benefits to society as a whole.
4. Encourage the the innovation and entry. The elite can accomplish this with low levels of taxation for desirable innovations. Moving beyond our framework, it is easy to imagine that the elite could even subsidize the supply of the innovation. In that case, the elite would also deregulate entry.

An important feature of the model is the existence of an informal sector. Elite policy is constrained by the fact that the innovation may be implemented in the informal sector, which limits the extent to which it can be taxed or regulated but still allows production to contribute to supply and hence affect factor prices.

Inherent features of the innovation affect the elite's choices. For example, the elite's decision to appropriate and implement the innovation itself depends upon how easily *replicable* the innovation is. The elite's incentives to encourage an innovation are a function of its *complementarity* to elite assets, the more so the more *general-purpose* is the innovation. The elite's ability to tax and redistribute from the innovation can be limited by high *entry costs* that limit competition in the supply of the innovation. Taxation of a *mobile* innovation will be limited by its ability to move to another jurisdiction. Taxation and regulation of an innovation that is easily *concealed* will be difficult, and complicated by the fact that its output will enter into local supply and affect factor prices. Note that these six features are not introduced by assumption, but rather emerge endogenously from the formal analysis.

Elite policy toward the innovation will combine some degree of direct implementation, taxation, and regulation. The combination of these strategies—affected by the character of the innovation—describes a battle for control over the definition and allocation of property rights that determines the equilibrium distribution of claims on future income (Spar, 2003), the stakes and the instruments of that battle.[2] We show that these strategies produce the four canonical outcomes described above: appropriation and regulation, taxation and deregulation, blocking, or encouragement and deregulation. We provide more detail on these canonical outcomes below.

Ours is a story about how an incumbent elite can use government policy toward productivity-enhancing advances to its own benefit—whether by blocking, restricting, or encouraging the innovation. Inasmuch as elite strategies toward innovation are an important factor in economic growth, the approach is of broad relevance to patterns of development.

We discuss the relation of the article to the existing literature in Section 2. Section 3 presents the formal analysis of how elite interests shape policy toward an innovation characterized by a combination of the six features. Section 4 gives another perspective on the predictions of the model, and provides illustrative evidence of its relevance and generality. Section 5 puts the implications of the model in perspective with a broader discussion of the political economy of innovations, and Section 6 concludes.

2 | RELATIONSHIP TO THE LITERATURE

In a world without transactions costs or commitment problems, there would be no elite opposition to innovation because the government could tax away rents and distribute them in full to the elite. But there are at least two sources of slippage: in taxation (due to, inter alia, concealability), and in distributing them to the elite. In a way our enterprise involves clarifying the features of innovations that may exacerbate (or reduce) this slippage. Most of the literature has considered factors unrelated to the innovation itself—institutions, culture, and the structure of the elite. In contrast, we focus our attention on features inherent to a particular innovation.

Conspicuously, members of the elite may be constrained by institutions (see, e.g., Acemoglu, 2008; Khan, 2002; Khan & Sokoloff, 2001; Mokyr, 1992, 1994, 2005), pre-existing property rights, the protection of guilds, or even customs. For example, many recent innovations are protected under the relatively extensive umbrella of contemporary intellectual property regimes. Notice that pre-existing property rights, when they are recognized and enforced, put the innovator on an equal footing with the owners of affected existing investments. With property rights, they can mobilize their stake to future wealth as much as owners of capital and try to influence the policy decisions of the elite. This extends to other institutions,[3] although we should keep in mind that the elite may selectively disregard inconvenient institutions, for example, native claims on land usage (as shown by Campbell & Anaya, 2008; Gómez Isa, 2019; Medina, 2016). An innovation may even be protected by customs: Becker and Pascali (2019) show how Catholicism protected Jews from competition in supplying certain financial services in Medieval Germany.

Sokoloff and Engerman (2000) also suggest that factor endowments affect how decisions are taken by the elite. We ignore potential differences—and agency relationships[4]—between economic and political elites, and ignore the relationship of the political elite to a broader electorate or higher moral principles. The elite is united by its wealth and power, even though the sources of wealth may vary: a diversified productive base implies heterogeneous elite economic interests.

Scholars before us have argued that particular features of an activity have political consequences. It is well established that political competition among jurisdictions constrains fiscal and regulatory policies on mobile assets (see, e.g., Boix, 2003; Mahon, 1996; Mokyr, 1994, 2008; Simmons et al., 2007; Milner & Solstad, 2020). Caselli and Coleman (2006) and, in a different framework, Silve (2018) find that asset holders facilitate the usage of an asset that augments their own. Jha (2013) shows that Muslim traders were safe from harm when dealing with Hindu partners in Indian ports, thanks to non-replicable links with overseas suppliers.[5] Sánchez de la Sierra (2019) finds differences in the form of local monopolies of violence created in response to demand shocks for bulky coltan and easy-to-conceal gold in the Democratic Republic of Congo. An increase in the demand for coltan led to the dismantling of fiscal and judicial administrations, and for gold, to their development. In the terminology of this paper, ease of concealment impedes rent seeking.[6]

We propose a unifying framework to analyze how these features of an innovation (and more) affect their political reception by entrenched economic interests. This matters for several reasons. First, empirical applications, such as the ones cited above, usually focus on one feature. We show that any combination of features can be theorized, keeping in mind omitted or unspecified factors. We show that features may matter differently in different time frames or for different geographical units of analysis (see Section 4). Second, we provide a general

formulation. This reveals the hidden assumptions in the functional forms commonly used in the literature (see the Appendix for details). Third, we highlight blind spots in the (mostly empirical) literature. To take one instance, it is something of a commonplace to argue that the threat of defection forces the state to cater to the owners of "mobile assets" to be able to tax them (Bates & Lien, 1985; Hirschman, 1978). However, this argument conflates the mobility of assets with the ability to hide them, and ignores an important nuance. We note that ease of concealment both limits the ability of the state to tax and impedes the manipulation of factor prices. This means, for example, that for an innovation that complements existing elite assets and, unlike mineral extraction, can be concealed, the effect of being easy to conceal on taxation is ambiguous. Finally, we find interactions among these features, and show that their relative importance depends on the extent to which the elite can appropriate tax revenue.

3 | ELITE RULE WITH DISRUPTIVE INNOVATION

We start with a society dominated, formally or informally, by an economic elite. The elite earns rents from its privileged economic position; it therefore cares about the economic institutions that guarantee its rents. Policies here serve the wealthy. The elite controls economic policy, in particular fiscal and regulatory policy. Elite individuals also own a productive asset (capital).

We posit an exogenously developed technological advance—a novel idea, policy, technology, as well as a geographic or resource discovery—all considered as innovations.[7] If implemented, the innovation potentially provides rents to the innovators and those who deploy the innovation. It may also improve aggregate social welfare. From the point of view of the elite, the innovation might either improve or threaten existing investments and corresponding claims on future income; it could also be a source of tax revenue. We focus on innovations not anticipated by the elite that may severely affect existing patterns of social and economic activity (Rosenberg, 1996).

Fiscal and regulatory policies respond to two main motives on behalf of the elite: redistribution and factor-price manipulation. The state accomplishes the first by taxing the population (including innovators) and channeling funds into the hands of the elite. The state accomplishes the second by controlling entry and supply, either by regulation or by taxation, so as to manipulate factor prices to the benefit of the elite owners of affected capital.[8]

This section presents a formal model of this dynamic, which allows us to analyze the fiscal and regulatory response to an innovation. State policy affects the size of the rents to be earned and the identities of those who earn them; it also affects the extent to which the rents are taxed and redistributed. The analysis addresses two questions. First, will members of the elite allow the innovation or will they block it? Second, should the innovation be allowed, who will reap the rents (if any) accruing to it: innovators, the elite, a wider group in the population, or no one? The model allows us to delineate the assumptions we make and the logic of the argument.

We focus on the response of the elite to a given innovation, whose features help determine the elite's dominant strategy. We consider the following timing in the reception of an innovation:

0. Nature bestows an (unanticipated) innovation on the innovator(s).
1. The elite attempts to control the innovation and regulate entry.
2. Private third parties imitate the innovation if they can.
3. The elite implements a fiscal policy that consists of taxation and redistribution (to the elite).

4. Assets are supplied, output is produced and consumed.

See Section 5.2 for a discussion of the assumptions that underlie this timing. In what follows, we solve this game by backward induction. Once the elite becomes aware of the innovation and assesses its impact, its first concern is whether it can supply the machines itself, that is, appropriate the innovation (Section 3.5), or whether it must leave it in the hands of non-elite suppliers. In either case, it also controls the number of formal machine suppliers, $n \in \mathbb{N} \cup \{\infty\}$ (Section 3.4). Second, these decisions determine who, within and outside the elite, supplies machines. Third, the elite decides the taxation τ on the formal market for machines (Section 3.2). Taxation of formal suppliers yields revenue for the government which is passed on to the elite and, inasmuch as it affects the supply of machines, also affects the rents accruing to the elite from their own assets. Fourth, the market for machines clears, with n formal suppliers and a competitive informal sector. In Section 3.4, we show the particular interest of two particular subgames: monopolistic ($n = 1$) elite supply of M_f^{AE} machines, and competitive ($n = \infty$) formal non-elite supply of M_f^E machines. We consider the former in Section 3.3 (note that taxation is irrelevant in this case) and the latter in Section 3.1. We say that the elite appropriates the innovation if it supplies machines itself (i.e., $M_f^{AE} > 0$ in a monopoly, and $\mu_f > 0$ with non-elite suppliers). We say that the elite regulates entry if it affects n by its decisions.

Throughout the paper, we refer the reader to the Appendix for proofs and discussions of more formal aspects of our argument.

3.1 | Production and the structure of the economy

The economy is composed of two groups taking unitary decisions, the elite, which supplies inelastically an asset K, and a class of innovators. The innovators are inventors, entrepreneurs, explorers, or social leaders, and their contribution to the economy is in the form of a new asset, in quantity M. To facilitate the exposition, we refer to K as capital, and to M as machines, although we intend the concept of innovation to cover a broader array of economic developments than purely technological or mechanical innovations. One could imagine a landowning elite whose asset is land, and industrial innovators. A guild elite could confront a new factory system. An early manufacturing elite might face the rise of a new form of producing or of managing a corporation. A sheltered financial elite could face the prospect of opening the current and capital account to the rest of the world. In all cases, the new productive force or form would increase productivity, and also affect the activities of the incumbent elite. In the absence of any frictions or distortions in taxation and transfer, the elite could always be made indifferent to a welfare-improving innovation, so that our approach can be seen as focusing on aspects of innovations that create such frictions. In the version of the model we present, we keep workers and the supply of labor implicit.

There is one numéraire good produced and consumed under competitive conditions. It combines capital and machines according to a technology described by the twice differentiable and concave production function $G(K, M)$, with K and M the supply of each asset. Gross marginal returns to capital and machines are given by the partial derivatives G'_K and G'_M. The concavity of the production function ensures that marginal returns are decreasing (in particular, $G''_{MM} < 0$). To capture the potential complementarity of machines and capital,

our discussion features centrally the cross-derivative G''_{KM} (Caselli, 1999). If it is positive, the innovation is complementary to the elite's capital, augmenting its return: mechanical reapers, fertilizers, or railroads, for example, benefit landowners (Krusell et al., 2000). Conversely, if G''_{KM} is negative, the innovation is a rival of the elite's capital, supplanting the elite's capital: new methods of transportation that compete with existing elite-owned methods, or industrialization that threatens an agrarian elite by drawing labor away and raising wages (Comin & Hobijn, 2004, speak of "predecessor technologies").[9] In what follows, we will also sometimes need to characterize the innovation according to whether G displays increasing, constant, or decreasing returns to scale. An innovation that displays increasing returns to scale [IRS] has the property that for any combination of the factors $G''_{KM}K + G''_{MM}M > 0$. Because we have assumed that G is concave, a rival innovation displays decreasing returns to scale, and an innovation characterized by IRS is complementary.

Members of the elite own previously invested capital $\overline{K}$ in assets that the innovation would affect, either positively or negatively. An innovation may affect a narrow set of economic activities, therefore fewer owners of capital, and a small amount of $\overline{K}$. A general-purpose innovation (e.g., railroads, electricity, computers) affects many economic activities, a large proportion of the owners of capital, and a large amount of $\overline{K}$ (Rosenberg, 1963).[10] Our discussion features affected owners of capital $\overline{K}$ prominently. We do not take the general equilibrium effects of the introduction of machines on economy-wide returns to capital into account.

The economy includes a formal sector that the state can regulate and tax, and an informal sector which the state has greater difficulty reaching. The state can regulate and tax the formal supply of machines, but not the informal supply. The innovation's technology of formal supply is described by the (increasing) inverse supply function H; the possible technology of informal supply is described by the (also increasing) inverse supply function $\mathcal{H} > H$. It is more costly to produce machines informally, due both to the cost of evading the state and to the absence of the formal sector's economic and legal infrastructure. The innovators may apply the innovation in the formal sector—subject to the state's oversight, but also to its protection – in the informal sector, and abroad. In the informal sector, supply still affects domestic prices, an essential difference with applying the innovation abroad.

Equilibrium conditions for the competitive supply of machines are simple, and allow us to to introduce some notation. The elite may tax machines at tax rate τ. Capital is supplied inelastically, so equilibrium in the market for capital is $K = \overline{K}$. While the new asset may also be in limited supply as it is introduced (e.g., a newly discovered natural resource, or radio frequencies), we focus on equilibrium conditions with an elastic supply of machines (if the limited supply constraint is binding, the model and its conclusions become trivial). We characterize formal supply as M_f, informal supply as M_i; the aggregate supply of machines is $M = M_f + M_i$. To simplify notation, we specify the arguments M_f of H, M_i of $\mathcal{H}$, and $\overline{K}$ and M of G and its derivatives only when there is a possible ambiguity (see Appendix A for a discussion). Then, equilibrium supply conditions are

$$\begin{cases} (1-\tau)G'_M = H \\ G'_M = \mathcal{H}. \end{cases} \tag{1}$$

These conditions characterize the response of formal and informal supply to taxation. We assume that $G'_M(0) > H(0)$ to ensure that the innovation has any chance of being deployed. Let $M_f^O > 0$ be equilibrium formal supply of machines in the absence of an informal sector and in

the absence of taxation: $G'_M(M_f^O) = H(M_f^O)$, and let $\overline{M_i}$ be equilibrium informal supply of machines in the absence of a formal sector: $\overline{M_i} = 0$ if $G'_M(0) \leq \mathcal{H}(0)$, and $\overline{M_i}$ is defined by $G'_M(\overline{M_i}) = \mathcal{H}(\overline{M_i})$ otherwise. Let $\overline{\tau}$ be the tax rate above which formal supply is not profitable: $\overline{\tau} \equiv 1 - H(0)/\mathcal{H}(\overline{M_i})$ in the presence of informal supply, and $\overline{\tau} \equiv 1 - H(0)/G'_M(0)$ if $\overline{M_i} = 0$. Notice that in all cases, $\overline{\tau} \in (0, 1)$. With these notations, we derive the following result (proof in Appendix B):

Lemma 1. *If the supply of machines is competitive,*

1. *formal supply decreases in τ until $\tau \geq \overline{\tau}$, above which it is eliminated,*
2. *Below $\overline{\tau}$, informal supply*
   - *increases in τ if $\mathcal{H}(0) \leq G'_M(M_f^O)$,*
   - *if $G'_M(0) > \mathcal{H}(0) > G'_M(M_f^O)$, there exists $\underline{\tau} \in (0, \overline{\tau})$ below which it is crowded out of the market, and above which it increases in τ, and*
   - *if $\mathcal{H}(0) \geq G'_M(0)$, there is no informal supply at any τ, and*

   above $\overline{\tau}$, it is stable at $\overline{M_i}$. Finally,
3. *aggregate supply decreases in τ until $\overline{\tau}$, and then it stabilizes at $\overline{M_i}$.*

The intuition of Lemma 1 is simple: formal supply decreases as taxation increases, and informal supply may or may not increase to fill this gap. Figure 1 provides a visualization of the lemma. We focus first on the left side of the figure; the right side only illustrates how aggregate supply M can be represented as a function α of formal supply M_f.

Formal supply declines as the tax rate rises, going to zero when the tax rate is prohibitive, $\tau \geq \overline{\tau}$. In Figure 1 we do not present the case where informal supply never matters ($\overline{M_i} = 0 \Leftrightarrow \mathcal{H}(0) \geq G'_M(0)$), which is trivial; but even in the absence of informal supply (e.g., if the innovation cannot be concealed from the taxman), formal supply disappears when $\tau \geq 1 - H(0)/G'_M(0)$.

The technology of formal supply is more efficient than informal: formal supply crowds out informal supply at lower levels of taxation (completely when taxation is low enough in the case where $\mathcal{H}(0) < G'_M(M_f^O)$, corresponding to the upper panel of Figure 1). At intermediate levels of taxation both formal and informal supplies coexist. Formal and aggregate supply decrease with τ, while informal supply increases.

A corollary of Lemma 1 is that equilibrium in stage 4 of our game can be described without ambiguity either by taxation τ, equilibrium aggregate supply M, or equilibrium formal supply M_f. The right side of Figure 1 show aggregate supply as a function α of formal supply in equilibrium.

The shape of α reveals a crucial feature of the innovation, namely the ease with which supply shifts to the informal sector (Mayshar et al., 2017, use the adjective "transparent" to describe output that cannot easily be concealed). If α is flat, reducing formal supply by one unit leads to an increase of informal supply by (almost) one unit: this would be the case of an innovation that is easy to conceal, as owners move out of the formal and into the informal sector. Conversely, α' close to 1 reflects an asset that is difficult to conceal, so that producers cannot easily move from formal to informal supply, and cannot easily reduce formal supply and increase informal supply. This would be the case of major infrastructural or natural-resource

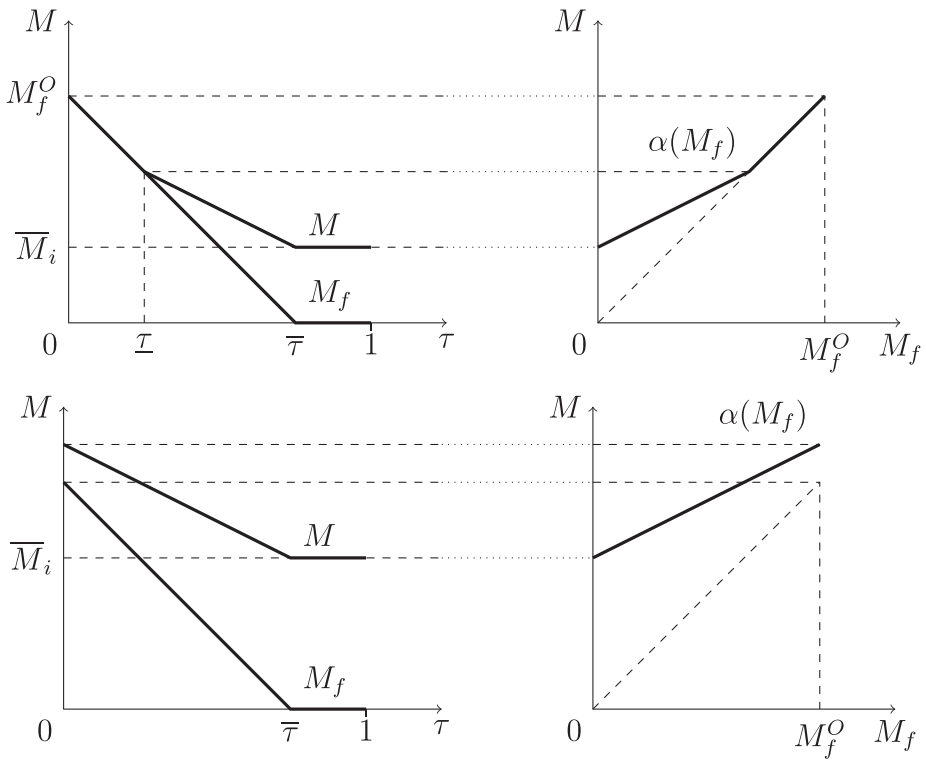

FIGURE 1 Stylized representation of the supply of machines as a function of the tax rate (LHS) and as a function α of formal supply (RHS). Top: $G_M^{'}(0) > \mathcal{H}(0) > G_M^{'}(M_f^O)$. Bottom: $\mathcal{H}(0) < G_M^{'}(M_f^O)$.

investments. This is important because it determines the efficiency and the reach of state policies. An innovation easily hidden cannot be taxed or regulated too heavily, simply because it would otherwise be applied out of the reach of the taxman or the regulator.

The slope of inverse supply H' captures the extent to which suppliers of the innovation can adapt to expected changes in economic or fiscal conditions by moving to another jurisdiction or hiding from the state. It conflates mobility and ease of concealment, although once a mobile asset is moved, its output does not automatically add to aggregate supply in its former jurisdiction, while the output of a concealable asset typically does (see Appendix A to disentangle mobility and ease of concealment). For instance, a railroad, tunnel or canal, or the point-source extraction of natural resources, are characterized by inelastic formal supply (i.e., steep H) – they cannot be moved or concealed. On the other hand, contractual or organizational innovations, trade secrets, and human capital can be easily taken to another jurisdiction or hidden (i.e., flat H).

To summarize, we consider the structure of an economy in which an innovation occurs, subject to taxation. In a simple setting, our analysis already reveals four features of the innovation that interact with taxation: complementarity or rivalry, narrowness or generality of purpose, mobility or location-dependence, and ease or difficulty of concealment. We will later introduce two other features of an innovation: replicability, and fixed costs of production. These affect the extent to which the elite would regulate and appropriate an innovation.

3.2 | Taxation

The elite controls the supply of machines indirectly through taxation. Implementable allocations correspond to $\tau \in [0, \bar{\tau}]$. Assuming a competitive supply of machines, this is equivalent to $(G'_M - H)M_f \geq 0$. Note that we assume that the elite either is the same as the owners of capital, or that it acts as its perfect agent (we relax this assumption later in our discussion of ϕ). Because the economic elite often delegates taxation to a political elite that acts as its agent, it can solve the collective action problem even though ownership and control of capital remains decentralized. This is the reason why fiscal policy maximizes the income of the elite (owners of capital). A fraction ϕ of all tax proceeds are redistributed among members of the elite. With these simplifications, we can write the full program of the elite in terms of M_f instead of τ (see Appendix C for a discussion):

$$\begin{aligned} \max_{M_f} U_E &= G'_K \overline{K} + \phi\Big(G'_M - H\Big)M_f \\ \text{s.t.} \quad & \Big(G'_M - H\Big)M_f \geq 0. \end{aligned} \tag{2}$$

where $G'_K \overline{K}$ is the income of the fraction of the elite whose activity is directly affected by the supply of machines, and $\tau G'_M M_f = (G'_M - H)M_f$ is the revenue from taxing innovators in the formal sector.

The elite, in other words, maximizes the combination of the return to its assets as affected by the supply of (new) machines, plus the taxes levied and redistributed to the elite. These two arguments in the elite's utility function correspond to the factor-manipulation and tax-and-redistribute functions of taxation in the model.

The parameter ϕ plays an important role here, as it affects the elite's return to taxation: the higher is ϕ, the greater the portion of taxes levied by the state that goes to the elite. This is subject to a number of interpretations; for our purposes we regard ϕ as capturing how completely the elite controls the public purse. The more pressure from the non-elite public forces the state to spend on public goods, the lower the elite share of tax revenue and the lower the value of ϕ; the more tax revenue the elite can command without diversion to public goods provision, the higher is ϕ. If fiscal revenue is used exclusively to provide elite-specific private goods, $\phi = 1$. If some of the tax proceeds have to be expended in the form of public goods, $\phi < 1$.[11]

In stage 3 of the game, an elite that does not appropriate and apply the innovation itself implements its preferred policy (see Appendix C).

Proposition 1. *If U_E is well-defined and strictly concave, then*

1. *If $\phi \leq \frac{\alpha'(M_f^O)G''_{KM}(M_f^O)\overline{K}}{H'(M_f^O)M_f^O - \alpha'(M_f^O)G''_{MM}(M_f^O)M_f^O}$, the elite does not tax machines.*
2. *If $\phi \leq -\frac{\alpha'(0)G''_{KM}(0)\overline{K}}{G'_M(0) - H(0)}$, it taxes machines prohibitively.*
3. *Otherwise, it chooses formal supply M_f^E such that*

$$G'_M - H = H'M_f^E - \alpha'\left(G''_{MM}M_f^E + G''_{KM}\overline{K}/\phi\right). \quad (3)$$

The elite may choose not to tax an innovation that is complementary enough with the elite's assets, especially if it receives only a small share of tax revenue (item 1 of the proposition). We refer to this as as the elite "encouraging" the innovation. Conversely, the elite prefers to tax prohibitively, in order to block, an innovation that is a substantial enough rival to its assets—again, if it receives only a small share of tax revenue (item 2 of the proposition). We refer to this as the elite "blocking" the innovation. In all other cases, the elite balances two concerns as it formulates its tax policy. The first concern is to extract maximum revenue from the innovators (presupposing that the elite receives a substantial enough share of tax revenue). The second is to use tax policy to influence the supply of the innovation so as to maximize the elite's return on its existing investments. Items 1 and 2 correspond to the corner solutions of this program, in which factor-price manipulation (as it is termed by Acemoglu, 2006) dominates taxation-and-redistribution, and item 3 characterizes the non-corner taxation" outcome.

The two arguments in the elite's utility function create tradeoffs in elite formulation of the preferred tax policy. For example, encouraging increased formal supply widens the tax base; however, with diminishing returns, it also reduces tax revenue per unit of formal supply. More generally, tax policy's impact on formal supply of the innovation also affects returns to elite investments—positively or negatively, depending on whether the innovation complements or rivals elite assets. ϕ directly affects how the elite weights the relative importance of the taxation-and-redistribution motive relative to factor-price manipulation. When ϕ is close to 1, so that tax revenue is channeled effectively to the elite, the elite can focus on this, even taking its concern about sunk capital $\overline{K}$ into account. As ϕ decreases, tax revenue is less surely redistributed to the elite, so that the impact of the innovation on the return to the elite's assets plays an increasing role. With lower ϕ such that the elite earns little from taxation, it has strong incentives to encourage a complementary innovation—so to tax it lightly if at all—while it has strong incentives to block a rival innovation.

Equation (3) illustrates how these conflicting incentives combine into a tax policy. To start with the LHS, the term $\tau G'_M = G'_M - H$ represents the tax revenue that can be raised from the marginal unit of formal supply, which is set with the above-mentioned concerns in mind. The first two terms on the RHS describe the optimal tax policy if the elite were only concerned with maximizing tax revenue—the peak of the Laffer curve. So $H' - \alpha' G''_{MM}$ describes the corresponding loss in revenue per unit as the tax rate is lowered, the result of two effects: the loss in revenue per unit due to attracting the marginal unit of formal supply $-\tau' G'_M = H' - \alpha' G''_{MM} H/G'_M$ and the additional loss in revenue per unit to compensate for decreasing returns $-\tau\alpha' G''_{MM} = \alpha' G''_{MM}(H/G'_M - 1)$. The third term on the RHS captures the impact of an additional machine on the returns to the elite's investment $\overline{K}$.

Equation (3) also illustrates the importance of several features of the innovation in the elite's decision to block, tax, or encourage it. The tax level depends on the interaction between the innovation and elite investments, as captured by $G''_{KM}\overline{K}$; on how easy it is to deploy the innovation abroad, as captured by H', or in the informal sector, as captured by both H' and α'. To characterize these multiple interactive effects, we adopt a heuristic inspired from comparative statics exercises (the fact that we characterize, for instance, mobility with H',

not a scalar but a function of M_f, prevents us from conducting such an exercise more formally. See Appendix C for details).

In line with the need to balance tax revenue with factor returns, the elite modulates its desire for tax revenue to increase the supply of a complementary innovation, or to obstruct a rival one. The elite taxes a complementary innovation less and taxes a rival one more—past the top of the Laffer curve (last term on the RHS of Equation 3). Whether the innovation can be appropriated (and applied directly) by the elite is possibly the single most important determinant of its fate. Its complementarity (or rivalry) with the elite's asset is a close second. This effect increases with the share of the elite's assets $\overline{K}$ affected by the innovation.

The elite taxes a mobile innovation less, and a location-dependent one more (first term on the RHS of Equation 3). The elite also taxes less an innovation that can be more easily concealed (also first term on the RHS of Equation 3). In that way, mobility and concealability look similar: they both simply limit the reach of state policies designed to tax and regulate the innovation.

Ease of concealment has a second effect: it also interacts with rivalry or complementarity, as revealed by the second term on the RHS of the equation. If the innovation is easily concealed, taxing it will have less impact on supply and therefore on factor prices. This makes the taxation-and-redistribution motive comparatively more powerful, so that the elite sets a tax rate closer to the top of the Laffer curve. Specifically, the elite taxes a more easily concealed rival innovation less: ease of concealment unambiguously reduces taxation on a rival innovation. It taxes an innovation that displays IRS *more* if it can be more easily concealed, and the sign of $G''_{MM}M_f^E + G''_{KM}\overline{K}/\phi$ is unclear for innovations that are neither rival nor IRS, which of the two effects dominates in those two cases is uncertain.

The elite has a clear incentive to limit taxation on an innovation that augments the return on its assets, to keep it from leaving the jurisdiction for a friendlier one. However, it faces no such incentive to limit taxation if the threat is that the complementary innovation would shift to the informal sector, as it would still add to supply.

To summarize, the elite uses taxation for two purposes. The first is to raise revenue from innovators for redistribution to the elite; the second is to affect the formal supply of the innovation, which allows the elite to manipulate prices to its advantage. Our analysis reveals many forces pulling in different directions (this framework does not point to a monocausal argument).

1. An innovation that complements the elite's capital is taxed more lightly to encourage supply.
2. The more general-purpose the innovation, the more important is factor-price manipulation relative to redistribution. This means taxing more a rival innovation, and less a complementary one.
3. A location-dependent innovation can be taxed more easily.
4. A rival innovation that is harder to conceal can be taxed more easily. The effect is ambiguous if the innovation is complementary.
5. At the limit, the elite may wish to block a rival innovation, though the innovation will still be supplied within the boundaries of the jurisdiction if it is easily concealed, and outside if it is mobile.

3.3 | Elite-controlled innovation

The elite can, under certain conditions, take control of the innovation, deploy it, and earn the rents (if any) associated with it. We cover in more detail below the factors that affect the elite's decision to appropriate the innovation or let it be developed by others. In this section, we consider how much the elite would supply of the innovation if it were under its control.

An elite that has appropriated the innovation has no incentive to tax itself, so there is no fiscal policy per se. If a member of the elite controls the innovation, the elite maximizes the sum of the utility accruing to that portion of the elite that does not control the innovation (including those affected by the innovation), plus the surplus of innovators in the formal sector. In the informal sector, a member of the elite cannot count on the legal protections of the state, and cannot be distinguished from a non-elite supplier. Hence, we can write the elite's program in compact form as

$$\max_{M_f} U_{AE} \equiv G'_K \overline{K} + G'_M M_f + \int_{M_f} H(m)dm, \tag{4}$$

where $G'_K \overline{K}$ is the income of those members of the elite whose assets are directly affected by the supply of machines, and $G'_M M_f + \int_{M_f} H(m)dm$ is the income the elite derives from controlling the formal supply of the innovation. The elite implements its preferred policy such that (see Appendix D)

Proposition 2. *If U_{AE} is well-defined and strictly concave, then*

1. *if* $\frac{\alpha'(0)G''_{KM}(0)\overline{K}}{G'_M(0) - H(0)} \leq -1$, *the elite supplies no machine.*
2. *Otherwise, it chooses formal supply* M_f^{AE} *such that*

$$G'_M - H = -\alpha'\left(G''_{MM} M_f^{AE} + G''_{KM}\overline{K}\right). \tag{5}$$

Propositions 1 and 2 reveal the similarities and differences in the supply by an "appropriating elite" as opposed to supply by non-elite innovators. In particular, there is no maximum supply here—when the non-appropriating elite does not tax the innovation (item 1 of Proposition 1). This is because we do not consider the possibility that the non-appropriating elite may subsidize a particularly desirable innovation. The appropriating elite may still choose to block an innovation under its control (item 2 of Proposition 1 and 1 of Proposition 2). This corresponds to an intuition already present in Arrow (1962), that "preinvention monopoly power acts as a strong disincentive to further innovation." Otherwise, the elite balances the interests of the elite members that deploy the innovation with the interests of those that the innovation affects. There are two differences in the trade-offs that the elites face: the appropriating elite does not need to worry about the exit of innovators, and it does not need to worry about the possibility that some of the tax revenue from the non-appropriated innovation might be diverted from elite-specific private goods.

As we can see from a quick glance at Equation (5), the appropriating elite's decision remains affected by the interaction between the innovation and the elite's prior investments, and how easy it is to deploy the innovation in the informal sector—but not by how easy it is to deploy the innovation abroad. Using the same heuristic as above, the elite supplies more of a complementary innovation, and less of a rival innovation. This pattern is emphasized by how general is the purpose of the innovation. Finally, the elite supplies more of a rival innovation if it is easier to conceal, and less if it displays IRS.

In Section 3.5, to determine the preferences of the elite with respect to appropriation, we will compare what it implements in either situation. For this, we need to compare the outcome under each elite. We define "surplus supply" as the difference $M_f^{AE} - M_f^E$, and note the following point (proof in Appendix E).

Corollary 1. *There exists a value of* $\phi_1 \in (0, 1)$ *such that for* $\phi > \phi_1$, *surplus supply is positive for any production function, and for* $\phi < \phi_1$, *surplus supply is negative in a boundary of any production function such that* $\alpha'(M_f^O)(G''_{KM}(M_f^O)\overline{K}/\phi + G''_{MM}(M_f^O)M_f^O) = H'(M_f^O)M_f^O$.

Supply is *generally* at least as large under an appropriating elite (i.e., surplus supply is positive). This is always the case if ϕ is large enough ($\phi \geq \phi_1$). This is also always the case for a rival innovation and for innovations *complementary enough*. If ϕ is low, factor-price manipulation becomes a strong motive for the non-appropriating elite, and there exist *moderately complementary* innovations that it would encourage more than the appropriating elite. At the limit, an appropriating elite blocks a smaller set of rival innovations (except if $\phi = 1$, in which case the elite blocks the same innovations whether it controls them or not). Our heuristic even allows us to go one step further in the comparison, albeit less formally: there exists a lowest value of $\phi_2 \in (\phi_1, 1)$ such that for $\phi \geq \phi_2$, supply of the innovation increases faster under the appropriating elite (see Appendix E).

3.4 | Regulation, deregulation, and imitation

Up to this point, we have focused on the elite's use of taxation both as a source of revenue and as a way to affect the quantity of the innovation supplied. However, the elite-controlled state can also dictate regulatory policy so as to affect who can bring the innovation to market. This is relevant to the elite inasmuch as it affects control of the innovation as it is brought into production.

To discuss regulatory policy, we first need to go back one step. To establish Lemma 1, we have made one significant assumption: that formal and informal supplies are competitive. If instead we considered n formal producers with an identical technology described by the inverse supply function H, each producer would supply m_f such that

$$H(m_f) = (1 - \tau)G'_M\left(1 + \alpha' G''_{MM} m_f / G'_M\right),$$

where the term $\alpha' G''_{MM} m_f / G'_M$ captures the market power associated with imperfect competition. A limited number of producers can affect the return on their assets by affecting

supply (notice that $\epsilon_d = G'_M/(G''_{MM}M) < 0$ is the elasticity of demand). The market power of an individual producer in the formal sector corresponds to its market share m_f/M, and is dampened if informal-sector producers are present (i.e., when α' is lower than 1). In equilibrium, the n identical producers supply the same quantity $m_f = M_f/n$. Assuming that the elite has not appropriated the innovation, from its perspective, the equilibrium supply condition now looks like

$$H(M_f/n) = (1-\tau)G'_M(1 + \alpha'/\epsilon_d \cdot M_f/(nM)). \tag{6}$$

Stage 2 of the game is straightforward: individuals both within and outside the elite imitate the innovator if they can. As long as the sector is imperfectly competitive, imitators earn rents on the innovation. If the innovation is easily replicable, imitators enter until they dissipate these rents. If there are fixed costs in production the industry remains imperfectly competitive, and oligopolistic suppliers earn some limited rents.In stage 1 of the game, the elite determines its policy toward the entry of the imitators, based on the expected impact of this entry on tax revenue and the return to elite assets.

$$\max_{\tau,M_f,n} U_E \equiv G'_K\bar{K} + \phi\tau G'_M M_f$$
$$\text{s.t.} \quad \begin{cases} H(M_f/n) = (1-\tau)G'_M(1 + \alpha'/\epsilon_d \cdot M_f/(nM)) \\ \tau G'_M M_f \geq 0. \end{cases} \tag{7}$$

To study the preferences of the elite over the structure of formal supply (i.e., n), we do not need to solve this program in full. First, while we have established Lemma 1 under competitive supply, we assume that its logic holds under imperfect competition: τ is uniquely determined by the elite's choice of M_f and n by the equilibrium condition, with $\partial\tau/\partial M_f < 0$ and $\partial\tau/\partial n > 0$. We can simplify the elite's program accordingly. Second, using the notation $\lambda_n \geq 0$ to denote the Lagrange multiplier associated with the condition $\tau G'_M M_f \geq 0$ (see Appendix F), and treating n as a continuous variable, with $V_E \equiv U_E(M_f^E)$, the envelope theorem yields

$$\frac{dV_E}{dn} = (\phi + \lambda_n)G'_M M_f \frac{\partial\tau}{\partial n} > 0 \tag{8}$$

taken at optimal values M_f^E and M^E.

Proposition 3. *The non-appropriating elite does not regulate the formal supply of machines, and encourages entry and competition.*

The elite benefits from more rather than fewer suppliers of machines. With a given level of formal supply, increasing competition (to $n+1$ firms) means fewer rents for the suppliers and more tax revenue, which unambiguously benefits the elite; and the elite can even do better than holding formal supply constant, since M_f^E does not maximize U_E with $n+1$ competitors.

The elite thus facilitates (does not regulate) the entry of imitators. Notice that a policy of free entry may not lead to a competitive supply: the innovation may be difficult to replicate by imitators, or equilibrium competition may be limited by large costs of entry.

For an elite that appropriates the innovation, there are slightly more complicated (and more surprising) results. An elite that appropriates the innovation faces potential competition from $n-1>0$ other formal suppliers. We evaluate the elite's problem in light of four choice variables, the tax rate τ on formal supply, elite (formal) supply μ_f, aggregate formal supply M_f, and the number of private formal suppliers n:

$$\max_{\tau,\mu_f,M_f,n} U_{AE} \equiv G'_K\overline{K} + (1-\tau)G'_M\mu_f + \int_{\mu_f} H(m)dm + \phi\tau G'_M M_f$$
$$\text{s.t.} \quad \begin{cases} H\left(\frac{M_f-\mu_f}{n-1}\right) = (1-\tau)G'_M\left(1+\alpha'/\epsilon_d \cdot \frac{M_f-\mu_f}{(n-1)M}\right) \\ \tau G'_M(M_f-\mu_f) \geq 0. \end{cases} \tag{9}$$

Here too, we avoid solving this program in full, although Appendix G provides a few useful additional considerations. Using the notation λ_{AE} to denote the Lagrange multiplier associated with the second condition, with $V_{AE} \equiv U_{AE}(M_f^{AE}, \mu^{AE})$,

$$\frac{dV_{AE}}{dn} = (\phi M_f - \mu_f + \lambda_{AE}(M_f-\mu_f))G'_M\frac{\partial\tau}{\partial n}, \tag{10}$$

again taken at optimal values M_f^{AE}, M^{AE}, and μ_f^{AE}. Interestingly, this reveals V_{AE} to be a quasi-convex function of n (see Appendix G), and suggests two main candidates for the elite's preferences with respect to the structure of the supply. Either the elite prefers $n=1$, that is, a monopoly, or it prefers n large, that is, competitive supply. If $\phi=1$, V_{AE} increases with n: it is more profitable for the elite to tax (many) competitive suppliers than to produce much itself. If $\phi<1$, it decreases, then increases with n: only a fraction of tax revenue accrues to the elite, and it may become more tempting for the elite to earn rents from exploiting the innovation. Moreover, the innovation may be difficult to replicate, entry may be limited by large costs of entry or other institutional factors that protect innovators from imitation by third parties. All these factors would limit the benefit to the elite of allowing others to implement the innovation. Finally, when $\phi=0$, it prefers to supply machines as a monopoly.

Proposition 4. *There exists $\phi^* \in (0,1)$ above which the appropriating elite's preferred policy is open entry to supply of the innovation, and below which the elite's preferred policy is monopolistic supply by the elite. ϕ^* increases in the presence of large costs of entry.*

Interestingly, when all tax revenue goes directly to the elite (i.e., when $\phi=1$), the elite has an interest in the greatest possible implementation of the innovation, so as to maximize tax revenue *even if it means competing away any rents they might derive directly from imperfect competition*. This goal is tempered by the (undoubtedly common) circumstance in which the elite has to share tax revenue with other public or private purposes. When $\phi<1$, there is another possible equilibrium where the appropriating elite would prefer to eliminate formal-sector competitors, limiting both the supply of machines and entry. In this case, the elite erects barriers that protect its rents, at some social cost (Tullock, 1967).

To summarize, this section reveals a striking difference between the appropriating and the non-appropriating elite. Appropriation and regulation go hand in hand: the elite benefits from appropriation only if it can limit the entry of private competitors. In turn, limiting entry only

makes sense if the elite cannot hope to directly benefit enough from taxation, that is, if ϕ is low enough. If the elite benefits from taxation, it prefers competition, and deregulates entry accordingly. In that case appropriation brings only limited benefits.

3.5 | Appropriation

In stage 1, the elite considers whether to appropriate the innovation. The elite considers the "replicability" of an innovation as it determines whether and how to appropriate, regulate, tax, encourage, or blocking the innovation. An innovation that is not replicable constrains available strategies at two stages: it may prevent appropriation by a member of the elite, and it may also prevent the entry of private imitators, even if the elite chooses to allow open entry to supplying the innovation.

If appropriation were costless the elite would appropriate every innovation. Absent any cost to appropriation, consider the decomposition of $U_{AE}(M_f^{AE}) - U_E(M_f^E)$ into two terms: $U_{AE}(M_f^{AE}) - U_{AE}(M_f^E)$ is nonnegative because M_f^{AE} maximizes U_{AE}, and $U_{AE}(M_f^E) - U_E(M_f^E)$ is the positive income of an innovator under a non-appropriating elite.

Examples of innovations that the elite can appropriate costlessly abound. Some ideas, once revealed, immediately become self-evident to all, such as the assembly line and the Fosbury flop, cf. Goldenberg et al. (2010). Appropriation is costless when innovations give value to an asset that people did not use before, and had not bothered (or thought) to regulate. Spar (2003) suggests several instances of such innovations. Soon after the invention of the radio, for instance, states stepped in to regulate the usage of electromagnetic waves for wireless transmission, effectively creating property rights where none existed, to the benefit of the elite.

For some innovations, replication is only a matter of investing enough time, energy, and possibly money. Even if appropriation comes at a cost, the elite may be willing to pay that cost if the benefits are sufficient, as is often the case with military technology, for instance. But appropriation may be too costly. Some innovations are simply not technically replicable.

If it is costly to appropriate the innovation, the elite may prefer instead to tax private suppliers (Propositions 3 and 4). In practice, this choice is complex due to variation in the difficulty of the elite and others to replicate the innovation. An appropriating elite may not be able to eliminate all competition if replication is relatively easy. Conversely, difficulties in replication may limit the elite's ability to stimulate entry and competition.

In this section, we simplify the discussion by comparing two extreme situations: an appropriating elite that would eliminate all formal competitors ($n = 1$), and a non-appropriating elite that effectively eliminates the market power of non-elite suppliers (n large). To simplify the discussion, we write the benefit of appropriating the innovation with notations used in Section 3.4 and abstract from ϕ (i.e. taking $\phi = 1$) for a moment:

$$V_{AE}(1) - V_E(\infty) = \int_{M_f^E}^{M_f^{AE}} \left(\alpha' G''_{KM} \overline{K} + \alpha' G''_{MM} m + G'_M - H\right) dm + \int_0^{M_f^E} H' m dm. \tag{11}$$

Equation (11) illustrates the importance of several features of the innovation to the elite's decision to appropriate the innovation, on the one hand, or to block, tax, or encourage it, on the

other. In particular, these include the impact of the innovation on the elite's investments, and the ease with which the innovation can be deployed abroad or in the informal sector. We consider each in turn. (We defer the discussion of concealability whose effect is ambiguous to Appendix H, and add a discussion of fixed costs of supply.)

The benefit of appropriating the innovation is *generally* larger for a complementary innovation, especially if the elite captures a large share of tax revenues (even if, as we show in Appendix H, if we need to qualify this assertion rather severely).

The effect of complementarity or rivalry is magnified by the extent to which the innovation has general effects.

The elite has greater incentives to appropriate a mobile innovation than a location-dependent one. This is because if the elite controls the innovation it can exploit it regardless of its mobility, while a mobile innovation not controlled by the elite would be harder to tax. $\phi < 1$ attenuates the impact of mobility on the elite's benefit from appropriation, but does not change its sign.

Finally, large costs of entry limit the extent to which the non-appropriating elite can control entry and competition. As a result, they unambiguously increase the benefits of appropriation.

We can summarize the factors that affect the elite's strategy with respect to appropriating an innovation. Once again, our analysis reveals several forces pulling in different directions.

1. The more complementary the innovation is to the elite's assets, the more attractive it is for the elite to appropriate the innovation (if ϕ is large enough).
2. The more general-purpose is an innovation, the more it magnifies the impact of complementarity on the incentive to appropriate.
3. The more mobile the innovation, the greater the elite's incentive to appropriate it.
4. Finally, the greater the entry barriers, the greater the incentives for the elite to appropriate the innovation.

4 | DISCUSSION AND ILLUSTRATIONS

There are many implications of the model developed above. It speaks to the impact of the six features we have considered, both on their own and in interaction with one another. It leads to expectations about the circumstances in which innovations will be adopted by a society, and in which they generate rents, and for whom. The analysis suggests when an incumbent elite will adopt an innovation itself, or allow others to adopt it, or block it (Section 4.1). In this section, we return to the motivation for this theoretical exercise to illustrate how the model structures explanations of patterns of receptivity or resistance to innovation. We start with a description of four particularly prominent outcomes of elite response to innovations, ranging from adopting and accepting them enthusiastically to blocking them. We then turn to some empirical illustrations of how our theory helps explain the adoption, blocking, or otherwise of innovation by an elite.

4.1 | Four canonical outcomes

The willingness and ability of a ruling elite to accept new economic activities—new technologies, policies, or ideas—has a powerful impact on broader patterns of economic growth and development. In this context, we are particularly interested in cases in which an

incumbent elite blocks or restricts the scope of welfare-improving innovations, or conversely permits and encourages them. We can simplify somewhat the logic and implications of our theory along these lines by describing conditions we associate with the four canonical outcomes we suggested earlier.

4.1.1 | Appropriation

The incumbent elite always has an incentive to take over the innovation, but is not always able to do so. The elite's incentive to appropriate the innovation increases with the extent to which the innovation complements the elite's assets and has a general impact (at least when $\phi \geq \phi_2$). Mobility and large upfront investments also increase the elite's incentive to appropriate the innovation. Mobility matters because appropriation removes the threat of flight to another jurisdiction. Upfront investments matter because they would allow outsiders to earn monopoly rents in the sector, limiting the benefit to the elite.[12] Empirically, we can think of this as a category in which the incumbent elite allows the innovation, but insists on controlling it itself —even if this means it will extract monopoly rents in its provision (hence supply less of the innovation than would be socially optimal).

Although appropriation may have benefits for the elite, it can also be costly or simply impossible, as discussed above. The elite's ability to appropriate an innovation depends upon its replicability. If the elite cannot replicate the innovation, for whatever reason (perhaps technical), it will have to let somebody who can do so implement the innovation. If so, the elite has a continuum of strategies that range from blocking to encouraging the innovation.

4.1.2 | Blocking

An incumbent elite's incentive to block an innovation increases in the extent to which the innovation rivals (competes with) the elite's assets and in the extent to which it is of general impact. The reasons are straightforward: a rival, general-purpose innovation threatens the elite's economic interests directly. At the same time, the less concealable is the innovation, the more effective would be the effort to block it. Empirically, we can think of this as an instance in which the incumbent elite blocks a welfare-improving advance.

4.1.3 | Taxation

Alternatively, the elite allows the innovation, does not take it over, but taxes it, balancing two different motives: *taxation-and-redistribution* and *factor price manipulation*. A desire for revenue alone would lead the elite to seek to maximize tax revenue, at the top of the Laffer curve. The fact that taxation also affects supply of the asset and thus returns to the elite's assets, however, leads the elite to "over-tax" a rival innovation and "under-tax" a complementary one. The more complementary or rival and the more general-purpose is the innovation, the farther away from the top of the Laffer curve (on the respective side) the elite sets the tax rate. The elite sets a lower tax rate on a mobile innovation, to avoid driving production abroad. If the innovation is easy to conceal, taxation has less of an impact both on tax collection and the supply of the innovation. For a rival innovation, the two effects point towards lower taxation;

for a complementary innovation, however, the manipulation of factor prices that justifies under-taxing becomes less efficient, which leaves us with an ambiguous decision for the elite. The elite encourages entry and competition, to augment the share of the surplus that it can take for itself.

4.1.4 | Encouragement

Finally, an incumbent elite's incentive to encourage an innovation (i.e., not tax it—even, potentially, to subsidize a highly complementary innovation) increases in the extent to which the innovation complements the elite's assets and in the extent to which it is of general impact. The reasons are again straightforward: a complementary, general-purpose innovation enhances the elite's economic interests directly. Incentives to encourage an innovation increase in its mobility. Again, the elite encourages entry and competition. Empirically, we can think of this as a category in which the incumbent elite encourages the innovation both in its own interests and (coincidentally, not altruistically) in the interests of society as a whole.

4.2 | Blocking or encouraging: Railroads

The railroad first came to China in 1865, when a foreign merchant built a demonstration line in Beijing. The Imperial Government had the line torn up. Eleven years later, a group of foreign merchants opened a 10-mile railroad line in the Shanghai region. Within less than a year the Imperial viceroy ordered it, too, to be dismantled. Over the succeeding decades, China's economy stagnated, falling farther and farther behind the rest of the world. As late as 1900, China had only 292 miles of rail in place.

The railroad first came to Argentina in 1857, at a time when the country was a rural backwater. Domestic and foreign investors piled enthusiastically into the sector. Along with the steamship and refrigeration, the railroad revolutionized the country's economy by making it practical to transport its abundant wheat and beef from the pampas to Europe. By 1914, the Argentine railway network was roughly as extensive as that of Great Britain, and Argentina was richer than all but four countries in the world.

Why did some countries welcome this extraordinary innovation in land transportation, while others resisted it? Clearly railroads were an innovation of enormous general impact—the greatest advance in land transportation since the wheel—and were immobile and not concealable. This heightens interests and makes it crucially important to know whether railroads were complements or substitutes to elite economic activity. In the Chinese case, railroads would have (and eventually did) allow foreign goods to penetrate the local market, with major negative effects on elite economic interests; they could be blocked, and they were. In the Argentine case, railroads were quite the opposite: by dramatically cheapening the cost of transport to export markets, they were a crucial complement to the country's landholding elite. Here railroads were encouraged, as was the entry of domestic and foreign investors to increase supply. Sometimes rail transportation was even subsidized. The polar outcomes are expected given the general-purpose, immobile, and not concealable nature of the innovation.

4.3 | Taxing or appropriating: Raw material extraction (and canals)

The technology to exploit a raw material deposit is another innovation that can be important, especially in developing societies. Although there is variation, the most common situation is that the resource is first and foremost of interest to the elite as a source of tax revenue. The resource could be a complement to the elite's assets if it is an input into their production, but this is unusual—most such primary production is for export. Certainly the new ability to mine a natural resource is not a substitute for the elite's assets, especially when (as is usually the case) it uses little local labor. Such primary production normally requires substantial up-front costs, and inasmuch as there are other potential deposits elsewhere it can be regarded as mobile—that is, there is an incentive for the elite to encourage it in its territory. In line with these considerations, governments almost everywhere incline toward ownership (or tight control) of the mining of raw materials—oil wells, copper mines, and the like.

There is an interesting twist in thinking about the political economy of raw material extraction, having to do with replicability. From the standpoint of the society where the raw materials are found, the innovation is the ability to extract them—exploration and mining technology. If this is readily accomplished by the incumbent elite—if it is easily replicable—then the elite will apply the extractive technology itself and earn the rents accruing to the resource. However, it is common for a developing country not to have the ability to replicate the technology itself, in which case the next best policy is to permit others to exploit the resource and tax it optimally. Over time, as the society learns about the mining technology, it becomes replicable—and the government nationalizes it. This in fact describes the course of resource exploitation in many developing societies (Frieden, 1994, and see also Vernon, 1971).

The Suez and Panama canals may be seen as analogous to a major natural resource that exists only as the result of quite extraordinary technological innovations. Their history indeed parallels that of the natural resource bases. Unlike domestic canals—which are analogous to railroads—these are largely irrelevant to pre-existing domestic economic activity and serve primarily as a source of tax revenue. When, initially, the host societies were incapable of implementing or managing the technology, the host government permitted foreign ownership. As local capability—replicability—grew, the host government eventually appropriated the canals.

4.4 | Suggestive broad patterns

Other scholars have looked at the pattern of technological innovation and diffusion from both theoretical and empirical perspectives. In a series of articles using a database of innovations in the past several centuries, Comin and Hobijn (2004, 2009) analyze intercountry differences in technology adoption.

Two of their findings are particularly relevant to our approach. First, they find that more trade-open societies are more likely to adopt innovations. They suggest that trade encourages more acceptance of innovation as incumbents need it to face international competition—the technologies are more likely to complement incumbent assets. It is also the case, we suggest, that economic elites in trade-open societies are more likely to already be invested in economic activities that are closer to the technological frontier, thus less threatened by innovations on this margin. They are also likely to be more diversified, and therefore less threatened by any single innovation.

Second, they find that political institutions that empower narrower economic interests—a more limited elite—are more likely to resist innovation. In a study of the political economy of innovation and economic dynamism, Solstad (2020) similarly finds that countries with a narrower elite coalition are more resistant to innovation. These findings suggest, in our framework, that a narrower ruling coalition finds more innovations to be rival—or, conversely, that a broad ruling coalition finds fewer innovations to be rival.

4.5 | The political economy of financial services provision

Financial development is a central theme in modern economic history, from Venice and Genoa through the City of London to the present day. Yet there are substantial differences in the extent to which societies accept or encourage financial development. Financial innovation—from double-entry bookkeeping to modern international finance—has involved major advances over the centuries. Finance is, of course, both general-purpose and mobile, as bankers can take their business elsewhere. Depending on the era, it may or may not be replicable. Financial development may complement elite assets by providing capital; but it could also threaten the incumbent elite by making capital available to rivals.

In the seventeenth and eighteenth centuries, western European elites were in need of capital to expand their trading and industrial interests; they welcomed financial development but appropriated it, often as part of the establishment of new central banks. More generally, Rajan and Zingales (2003) find that countries open to trade and capital flows, both of which increase the elite's desire for financing, are more likely to embrace financial development, defined as "the availability of arm's length market finance." This certainly appears to be the pattern that has generally prevailed in developing countries: for most of the 20th century, they severely restricted financial development, but as trade and capital flows grew they embraced it. This is consistent with the view that the elite originally limited rivals by strictly controlling access to finance, but as external conditions changed they permitted financial development as a complement to their own economic activities.

As this indicates, elites have incentives to block financial innovation if it is going to strengthen rivals. Benmelech and Moskowitz (2010) find that more elite-dominated American states were more likely to impose usury laws that favored incumbents and restricted innovation. Becker and Pascali (2019) find both patterns. In German regions where religious doctrine prohibited lending by Catholics, Jewish bankers were welcome as complements to local elites. But with the Reformation in Protestant areas, with restrictions on lending by Christians loosened, Jews were more likely to be persecuted as rivals—especially where they were significant potential competitors to Christian financiers.

5 | EXTENSIONS

The model developed here focuses on the purely material motivations of the elite, but innovation also has political and cultural consequences (Section 5.1). In this section, we discuss some of these broader non-economic aspects and implications. Finally, we reconsider the underlying assumptions in the timing of the model in Section 5.2, and suggest how our model could relate to a wider set of stylized facts.

5.1 | Material incentives, political power, and identity

The framework we propose addresses the contest over the rents of innovation, and brings together six features that until now have typically been considered separately. There are at least two other sources of opposition to innovation that this paper does *not* address: when it threatens the sources of someone's power (Acemoglu & Robinson, 2000; Solstad, 2020), and when it threatens someone's culture and identity (Juma, 2016; Mokyr, 2016). We do not believe we can address culture, but we believe that our framework can be accommodated to discuss power.

In many aspects the contest over political power accentuates the contest over rents. Allowing innovators to derive rents from their innovations implies, in some cases, that they will command vast resources in the future. With such resources, they may in turn claim some sway over policy decision making and over institutions—in a word, entry into the elite. Following in the steps of Veblen (1908), Pistor (2019) recently argued that the law is not only a defining element of capital and wealth, it is also a crucial element of any asset's income-yielding capacity. In the worst-case scenario, the innovators challenge the incumbent elite's rule, and establish a new regime, that may be less protective of the incumbent's wealth (Acemoglu, 2003; Powell, 2004). If political power indeed depends on having access to resources (Acemoglu, 2006; Collier et al., 2009), the incumbent elite may prefer to starve the innovators, even at a cost to itself, rather than allow entry, dilution of its political power, and loss of control over the regulation and taxation of the innovation (in line with the view in Solstad, 2020). The importance of this mechanism may explain the common view that the weaker the state, the more innovation (Mokyr, 1992), although our analysis shows the need for a more nuanced picture.

5.2 | The timing of the game

The timing of the game reflects a simplified description of real life. It leaves aside some observations that could lead to interesting extensions of the model.

First, the elite sometimes allocates property rights based on the recognition of de facto utilization of an asset. In Roman law, *occupatio* was one of the common modes of acquisition of land, and *res nullius*, of personal property. More recently, in common law, the concepts of 'adverse possession' and "acquisitive prescription" recognize that continual possession or occupation of land translates into legal ownership of (under conditions that vary by jurisdiction), or even sovereignty over land (Lesaffer, 2005). The concept generally applies to land, but it has also recently been used for intellectual property (Bagley & Clarkson, 2003) and patent law (Broder, 2007). This implies that the definition of property rights does not always anticipate entry and imitation of an innovation: sometimes, it reacts to an established situation. In other words, stage 1 does not always precede stage 2. With this in mind, our framework remains best adapted to study property rights inasmuch as they are driven by the elite's redistributive goals (Sections 3.4 and 3.5).

Second, the elite sometimes changes the fiscal rules after the investment has been made (in other words, after the fixed costs of production have been paid). Governments cannot convincingly make commitments to bind their future actions (Acemoglu, 2003). Ex post renegotiation of fiscal policy (or even outright expropriation of investments) may affect the supply of the innovation as we described in Section 3.1. For instance, Frieden (1994) discusses this hold-up problem in international investment and its institutional consequences. This observation implies that stage 3 does not always precede stage 4. While we abstract from ex post

renegotiation between the inventor and the elite, our framework adequately captures a setting where inventors take investment decisions anticipating correctly the actual implementation of the fiscal policy, even if this implementation does not correspond to ex ante fiscal promises.

6 | CONCLUSION

Whether societies embrace innovations or resist them plays a powerful part in their economic growth and development. Modern economic history is replete with striking examples of rapid technological adaptation, and retrograde resistance. In this article, we have attempted to provide a theoretical lens with which to understand which innovations are most likely to be resisted, and which societies are most likely to resist them. We have focused on inherent characteristics of the innovation, and of the society.

We posit a ruling elite that controls government policy, which it can use to tax and spend. This fiscal policy has two goals. The first is to affect the supply of productive factors to the economy, taxing more heavily those whose supply it would prefer to limit. The second is to redistribute income from those taxed to the elite. We study considerations that affect the balance with which the elite-controlled government pursues the first goal—factor supply manipulation—rather than the second goal—redistribution—and the extent to which it does either.

Our analysis emphasizes the nature of the ruling elite's economic assets, starting with whether they are complements or substitutes to the innovative technology, product, process, or policy. Naturally, the more the innovation complements the elite's assets, the more enthusiastic the elite is about the innovation; and the more the innovation rivals the elite's economic activity, the more the elite attempts to limit or suppress it. The elite, for example, will tax a strongly rival innovation so heavily as to effectively block it from being supplied, while it will not tax and perhaps subsidize a strongly complementary innovation.

In addition, we ask whether the elite will adopt the innovation itself, or will allow it to be exploited and implemented by others in the society. All else equal, the elite would prefer to control the innovation itself. However, there may be technical or other reasons why the elite cannot itself put the innovation into production—the innovation may not be easy to copy or replicate. Replicability by individuals who are not in the elite will also determine how effectively the government can discourage or encourage entry, hence supply of the innovation. As a result, replicability will affect the ability of the government to tax the innovation to redistribute to the elite.

Other features of the innovation also affect the elite's policy toward it. Whether the innovation can be easily concealed from the fiscal authorities, and whether it can be simply moved to another jurisdiction, affects the policy pursued. Similarly, whether the innovation has a broad, general-purpose, impact on economic activity, or rather a narrower one affects the elite's attitudes toward it. So too does whether the innovation requires large upfront investments, even if the innovators are not credit-constrained, and even if the elite is not interested in taking away the value of these investments.

From these features of the elite and of the innovation, we derive expectations about the elite-dominated government's policies toward the innovation. These policies run the spectrum from welcoming and encouraging the innovation and its supply, through limiting it both to affect its supply and to raise revenue that can be redistributed to the elite, to blocking the innovation.

We use our theory to structure a brief comparison of the different response of two countries to the same innovation (the railroad). We further illustrate how the passage of time can affect the response of an elite to a novel technology. We summarize results from multi-country analyses by others that appear consistent with our theory, and suggest an application to the acceptance or less of financial development and modernization in both historical and contemporary contexts.

Our theory does not take into account the potential political impact of an innovation, an issue addressed by other scholars. It also ignores other non-economic causes and effects of innovative activity and its reception. Nonetheless, with a relatively spare theoretical apparatus we derive important implications of the economic and technological factors we address, for which we provide some illustrative examples.

The reception of innovation is central to the process of economic growth and development. This paper presents an integrated theory of some of the factors that influence whether a society will accept and adopt new ideas and technologies, or will resist and impede their use. Its implications are relevant to major issues in the political economy of economic growth and development.

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ENDNOTES

[1] As Michael Faraday is reported to have justified the utility of electricity to William Gladstone.

[2] The elite will also certainly care about the political institutions that provide it with the political power to enforce its privileged position. In this article, we consider the potential direct impact of innovation on political power only briefly in Section 5.1. It is a theme to which we hope to return. It is covered well by Acemoglu and Robinson (2000). We consider in details an indirect effect, by which political influence comes in proportion to the rents one commands. Political mobility is the result of shifts in the distribution of rents, of the rise of successful innovators and the decline of obsolete incumbents. Per Stasavage (2014), "a political regime results in the provision of property rights for a specific group, accompanied by significant barriers to entry." Regime change corresponds to institutions and property rights being adapted to reflect more faithfully the interests of rent-holders (also see Acemoglu & Robinson, 2006, 2008, for a discussion of the *de facto* power of elites in defining economic institutions).

[3] For instance, Blockmans (2010) shows how merchant guilds came to protect citizens on their travels in 11th to 13th century Europe.

[4] Comin and Hobijn (2009) consider these in more details.

[5] Levine and Sichelman (2019); Simon and Sichelman (2017) and Fromer (2019) also discuss trade secrets as another way to avoid replication (by the elite or by third parties): the contemporary accumulation of large amounts of personal data makes it very hard to imitate the services offered by certain tech companies, and gives them a large first-mover advantage.

[6] This is also in line with Bates and Lien (1985); Besley and Persson (2013); Hirschman (1978); Scott (2009) and Mayshar et al. (2017). Ahmed and Stasavage (2020) have a similar argument. They envisage concealability as

an issue of asymmetric information between the ruler and the citizens, and show that rulers were more likely to share their power with a council in the presence of information asymmetries.

[7] We envisage an innovation as the supply of a new asset. This immediately endows it with several attributes – the aforementioned features of the innovation. It clarifies how an innovation sparks a battle for control over the definition and allocation of property rights on machines, on a new design, a new way of combining known assets, on newly discovered mineral resources or a new usage for known resources, the emancipation of coerced workers, and so forth. We do not believe that the framework we propose covers well changes to the technology of conflict, another theme to which we hope to return.

[8] The elite may also use its power for political purposes, to avoid the emergence of new sources of wealth that would generate new claimants to political power. We leave aside this purely political motivation here and discuss it briefly in Section 5.1.

[9] G''_{KM} is closely related to—and has the same sign as—the (gross) Hicks elasticity of complementarity, that is, $G''_{KM}G/(G'_K G'_M)$. For a rigorous analysis of alternative definitions of substitution and complementarity, see Stern (2011). Empirically, determining the 'factor bias' of technological change has been a recurrent question in the economic literature (see for instance Acemoglu, 2002; Caselli, 1999; Rosenberg, 1969).

[10] To prevent any confusion, we avoid using the term "specific" altogether, tempting as it may be. In the academic literature, the term *specific* is used to describe sometimes a non-redeployable asset, sometimes a single-purpose asset, location-dependence, or even specialized human capital (Williamson, 1983). Common usage also refers to an asset whose purpose is narrow as *specific*. In context, the term could therefore be used in connection with four out of the six features we study: with replicability, complementarity, location-dependence, and with "general-purposeness."

[11] Another interpretation could be that of Acemoglu (2006), who defines ϕ as a form of state capacity, with lower levels of the variable representing "leakage" from the taxation system. This suggests thinking of ϕ as the efficiency of the bureaucrats who control taxation and redistribution. $1-\phi$ could also be interpreted as the degree of corruption of bureaucrats, although bureaucrats play no role in this model. ϕ is clearly an institutional parameter and therefore not our central focus in this paper. However, its interaction with features of the innovation is too important for us to ignore in the general approach we are adopting. Besley and Persson (2009, 2010) consider the determinants of other dimensions of state capacity: a natural extension of the model would be to explain the origins of cross-jurisdictional variation in ϕ.

[12] Note that this is a different argument from the hold-up problem in international investment: the elite may decide to step in even if it cannot expropriate the upfront investment already laid out by the innovator.

[13] It is easy enough to derive all of our results and formal comparative statics with parameterized production and supply functions, taking for instance linear marginal cost functions$S$, c_f, c_i, andc_a, and a production function of the form$a + bM + cK + dMK + eK^2/2 + fM^2/2$, with$d$ capturing the complementarity between invested capital and the machines and$f$ negative reflecting the decreasing returns to machines in the economy. Such a specification would ensure that all our features of interest are characterized by scalars, including, after a bit of algebra, α' and β'.

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APPENDIX A: MICRO-FOUNDATION OF H'

For simplicity, we have made two assumptions on$H$ and $\mathcal{H}$ in the main text: they are both univariate and increasing. That they increase simply means that individual suppliers crowd each other out. That they are univariate means that interactions between informal and formal supplies are limited to competition in the supply of identical machines to the production function G. Even if formal and informal supplies do compete (for instance, for a common asset), we can retrieve the initial formulation, that only requires a more careful description. Let us actually consider a more complete model of the supply of the innovation, formally and domestically, informally and domestically, and externally, and the corresponding three equilibrium conditions:

$$\begin{cases} (1-\tau)G'_M(M_f+M_i) = S(M_f+M_i+M_a) + c_f(M_f) \\ G'_M(M_f+M_i) = S(M_f+M_i+M_a) + c_i(M_i) \\ D'(M_a) = S(M_f+M_i+M_a) + c_a(M_a), \end{cases} \tag{A1}$$

where, in addition to the notations of the main text, M_a is the supply of the innovation abroad, where it faces the inverse demand $D(M_a)$, S is the marginal cost of producing the asset M for any of the three markets, and c is the marginal cost of bringing formal, informal, and foreign supply to their respective markets. We assume that S, c_i, c_f, and c_a are all increasing functions, and that D' is a decreasing function (as in the domestic market, we assume decreasing returns, or at least non-increasing returns to using the asset abroad). Equilibrium on the external market determines M_a as a function β of domestic supply $M_f + M_i$, with $0 < 1 + \beta' < 1$. If

domestic supply decreases by one unit, external supply increases by $-\beta'$ units. With this notation, we can rewrite the two domestic equilibrium conditions as:

$$\begin{cases} (1-\tau)G'_M(M_f+M_i) = S \circ (\mathbb{1}+\beta)(M_f+M_i) + c_f(M_f) \\ G'_M(M_f+M_i) = S \circ (\mathbb{1}+\beta)(M_f+M_i) + c_i(M_i) \end{cases}$$

which look very much like the equilibrium conditions in the main text, with $H = S \circ (\mathbb{1}+\beta) \circ \alpha + c_f$ (it is easy to verify that the proof of Lemma 1 remains valid, even when H and $\mathcal{H}$ are not univariate). Deriving this expression, we obtain that:

$$H' = (1+\beta')\alpha' S' + c'_f, \tag{A2}$$

with $\alpha' \in (0,1)$ capturing how hard it is to supply the innovation in the informal sector, $1+\beta' \in (0,1)$ how hard it is to move the innovation abroad, and S' and c'_f structural descriptors of the production and formal marketization of the innovation.

APPENDIX B: PROOF OF LEMMA 1

The only difficulty in establishing the lemma is to show that formal and aggregate supplies decrease with τ, while informal supply increases. The proof is in three steps. (1) An increase in τ must correspond to a decrease of aggregate supply, since *a contrario* by the first (competitive) equilibrium condition we would expect a decrease of formal and by the second of informal supply, an impossibility. (2) By the second condition, informal supply increases when aggregate supply decreases. (3) If aggregate supply decreases while informal supply increases, it must be that formal supply decreases.

APPENDIX C: NOTES ON PROPOSITION 1

In writing the program of the elite, we implicitly assume that the output is shared between the elite and the innovators in proportion to the marginal product of each factor and in proportion to how much of the factors enter in the production function. For example, for a constant-returns-to-scale production function G, we have $G(K,M) = G'_M M + G'_K K$. The first term is a natural proxy for the share of the output that would go to the innovators (formal and informal), and the second to the elite, although we could imagine other sharing rules. If the production function displays increasing or decreasing returns to scale, the discussion is made more complex because the two terms do not add up to $G(K,M)$, and it is not clear how the (positive or negative) residue would be allocated. We believe these two considerations to be interesting, but orthogonal to the purpose of our paper. To simplify the discussion, we assume that all decisions—output and policy—are based on economic returns of $G'_M M$ and $G'_K K$, respectively.

The proposition, then, is a simple consideration of the first-order condition associated with the program of the elite, including its two corner solutions.

We do not consider in details the *second order condition*. We avoid doing so not because it is obviously true (it is not, and this may be a limit to the generality of the proposition), but because the discussion of the concavity of U_E seems sterile. The second derivative of U_E comprises some second derivatives, such as α'', of whose sign we have no general intuition. Perhaps reassuringly, the second derivative of U_E has only two terms whose sign we know: $2\phi\alpha' G''_{MM} - 2\phi H' < 0$, that suggest that with reasonable parameterizations of the model, the second order condition would be verified.

In the discussion of the proposition (and throughout the paper), we propose considerations that look like *comparative statics* on objects that are mathematically not scalars, but functions. We only characterize general-purposeness by the scalar $\overline{K}$. We characterize location-dependence by β' (in the main text, we simply say that location-dependence is captured by H'), difficulty of concealment into informal supply by α', and complementarity with invested capital by G''_{KM}, all functions of M_f. There is no obvious total ordering of innovations by how location-dependent, easy to conceal, or complementary they are. What does exist are intuitive partial orderings. Formally, we say that an innovation is more location-dependent if the derivative of its local versus foreign supply β' is higher for a subset of positive mass, and lower nowhere. With this partial order imposed on innovations, we can compare the mobility of some, albeit not all, innovations. When we do, the comparison is highly intuitive. Identically, we can impose a partial order on innovations according to how easy they are to conceal (α'), and to their complementarity with invested capital (G''_{KM}). These considerations we propose throughout should be understood as relying on these partial orders—holding the other features constant—and formally, also holding decreasing returns on machines (G''_{MM}), marginal costs of aggregate supply S', and marginal costs of the formal marketization of the innovation c'_f constant.

These partial orderings, and the corresponding comparative statics, imply *no* concession in terms of the generality of our results—on the contrary. Any set of innovations on which we can impose a total ordering by complementarity, by concealability, or by mobility is a subset of the innovations that we consider here, and our results apply immediately. Parameterizing a set of innovations – for structural econometrics, or for further formal exploration of the properties of innovations, for instance—would keep all our results, and probably yield several more intuitions, although maybe not with the same degree of generality as ours.[13]

As a last clarification on Proposition 1, we often refer to three subsets of innovations: *rival* innovations, such that $G''_{KM} < 0$ for all values of M_f and K, *complementary* innovations, such that $G''_{KM} > 0$ for all values of M_f and K, and *IRS* innovations, such that $G''_{KM}K + G''_{MM}M > 0$ for all values of M_f and K. In the space of all possible production functions G, a small subset falls into one of these three categories. We are interested in these three categories for two reasons: (1) they occur frequently in formal and structural models, and (2) we can derive clear-cut general results about such production functions. Two technical comments on these subsets are in order. First, because we are always working under the assumption of decreasing returns to machines, that is, $G''_{MM} < 0$, IRS innovations are a subset of complementary innovations, and rival innovations are a subset of decreasing-returns-to-scale innovations. It is possible that an innovation may be complementary and display decreasing returns-to-scale. Second, with IRS, $\forall\ M_f \leq M, \forall\ \phi \leq 1, G''_{MM}M_f + G''_{KM}\overline{K}\ /\phi \geq G''_{MM}M + G''_{KM}\overline{K} > 0$. This consideration is useful when we consider the effect of the ease of concealment on taxation.

APPENDIX D: NOTES ON PROPOSITION 2

Again, the proposition is a simple consideration of the first-order condition associated with the program of the elite, including its corner solution. With the same caveats, we do not delve any deeper into the second-order condition.

In the paper, we look closely at the differences and similarities between the appropriating and the non-appropriating elites. To compare the utility of the elite in both cases, we need to add a term to U_E, corresponding to the opportunity cost of not producing the innovation for the non-appropriating elite, that is, $\int H(m)dm$. This term plays no role in the decision of the non-

appropriating elite, which explains why we overlooked it when we wrote the expression of U_E. It plays a role when the elite considers appropriating the innovation or not.

APPENDIX E: PROOF OF COROLLARY 1

Consider the non-appropriating elite when $\phi = 0$. The elite blocks a rival innovation, and does not tax a complementary innovation. In the absence of taxation, formal supply is M_f^O, characterized by $G'_M(M_f^O) - H(M_f^O) = 0$. If the innovation is complementary, with G''_{KM} larger than, but close to 0, the appropriating elite supplies M_f^{AE} such that $G'_M - H \approx -\alpha' G''_{MM} M_f^{AE} > 0$. Since $G'_M - H$ decreases with M_f, it means that $M_f^{AE} < M_f^O$. Define

$$\phi_1 \equiv \frac{-G''_{MM}\left(M_f^O\right)M_f^O}{H'\left(M_f^O\right)M_f^O/\alpha'\left(M_f^O\right) - G''_{MM}\left(M_f^O\right)M_f^O} \tag{E1}$$

and for $\phi < \phi_1$, the non-appropriating elite facilitates a larger supply of the innovation than the appropriating elite with a production function such that

$$\alpha'\left(M_f^O\right)\left(G''_{KM}\left(M_f^O\right) + \phi G''_{MM}\left(M_f^O\right)M_f^O\right) = \phi H'\left(M_f^O\right)M_f^O.$$

With a partial order on innovations by how mobile they are, we can imagine a number of norms in the space of innovations. Corresponding to any such norm, we can define the concept of a boundary of a production function as other production functions close enough to the first one. To fix ideas, consider the intuitive norm $|G''_{KM}(M_f^O) - F''_{KM}(M_f^O)|$ between production functions F and G.

The determinants of surplus supply, with the exception of $\overline{K}$, are functions H', G''_{KM}, G''_{MM}, α'. Spaces of functions are only partially ordered and do not have such an obvious associated measure as the Euclidean space, and therefore no corresponding concept of derivation. With these difficulties, we argue for the heuristic mentioned at the end of Section 3.3. If we consider G''_{KM} as a scalar parameter of the model for a moment, holding other features constant, we use the implicit function theorem with a (big) abuse of notations to write, for an interior solution,

$$\frac{d\left(M_f^{AE} - M_f^E\right)}{dG''_{KM}} = -\frac{\alpha'\overline{K}}{2\alpha' G''_{MM} - H'} + \frac{\alpha'\overline{K}/\phi}{2\alpha' G''_{MM} - 2H'}$$

where, for clarity, the first term on the RHS is taken at M_f^{AE}, and the second at M_f^E. Because $H' > 0$, holding α', G''_{MM}, and $\overline{K}$ constant between M_f^{AE} and M_f^E, the denominator of the second term is negative and larger than the denominator of the first term. When ϕ is close enough to 1, the second term is negative, but smaller in magnitude than the first term, which is positive. To be more formal, take two innovations that can be ranked by their degree of complementarity, and compare their formal supply under an appropriating and a non-appropriating elite. Following the logic of the implicit function theorem, we can laboriously show that when ϕ is

close to 1, surplus supply is larger for the more complementary innovation, that is, there exists a $\phi_2 > \phi_1$ above which surplus supply increases in the complementarity of the innnovation.

The reasoning is identical when we consider a "comparative static" on the ease of concealment, but less fruitful. Again, abusing notations, we would write

$$\frac{d\left(M_f^{AE} - M_f^E\right)}{d\alpha'} = -\frac{G''_{MM}M_f^{AE} + G''_{KM}\overline{K}}{2\alpha' G''_{MM} - H'} + \frac{G''_{MM}M_f^E + G''_{KM}\overline{K} \;/\; \phi}{2\alpha' G''_{MM} - 2H'} - \frac{(1+\beta')S'M_f^E}{2\alpha' G''_{MM} - 2H'},$$

where the last term on the RHS is positive, but where, for the first two terms, too many signs are contingent for any result to hold generally, and for any specific results to be interesting. The last term corresponds to the direct effect of concealment on the RS motive, that gives the elite an incentive to appropriate the innovation. The first two terms correspond to the interaction between concealment and rivalry/IRS, but their combined sign is inconclusive.

APPENDIX F: LAGRANGE MULTIPLIERS IN EQUATIONS (8) AND (10)

We have considered throughout that the elites cannot subsidize the production of machines, that is, establish a negative tax rate on the innovation. The Lagrange multipliers λ_n and λ_{AE} correspond to that assumption. Changing the assumption does not affect our results. It would just simplify Equations (8) and (10) by the corresponding terms.

APPENDIX G: NOTES ON AND PROOF OF PROPOSITION 4

We do not need to solve the appropriating elite's program in full.

(1) We rely on an intuition from Lemma 1. We assume that τ is uniquely determined by the elite's choice of M_f, μ_f, and n, by the equilibrium condition. Formally, we have only shown it in the competitive case. As before, we avoid to delve into this discussion, not because it is obviously true (it is not, and this is maybe a limit to the generality of the proposition), but because the discussion seems sterile. It would require again require careful consideration of third-partial derivatives of G and second derivative of α, of whose sign we have no general intuition.

(2) We change variables, and consider $X = \frac{M_f - \mu_f}{n-1}$. Holding M_f and n constant,

$$\frac{1}{n-1}\frac{\partial U_{AE}}{\partial X} = H(M_f - (n-1)X) - \frac{H(X)}{(1+\alpha' X/\epsilon_d)^2} - \frac{H'(X)X}{1+\alpha' X/\epsilon_d},$$

equal to 0 when $X = 0$ and negative when $X = M_f/(n+1)$. To establish that in equilibrium $\mu_f \in ((M_f - \mu_f)/(n-1), 1)$, we would like to verify that the second partial derivative of U_{AE} is negative. We can write

$$\frac{1}{n-1}\frac{\partial^2 U_{AE}}{\partial X^2} = -(n-1)H(\mu_f) - \frac{H'(X)}{(1+\alpha' X/\epsilon_d)^2} + \frac{2\alpha' H(X)}{\epsilon_d(1+\alpha' X/\epsilon_d)^3} - \frac{H'(X)}{1+\alpha' X/\epsilon_d} + \frac{\alpha' H'(X)X}{(1+\alpha' X/\epsilon_d)^2} - \frac{H''(X)X}{1+\alpha' X/\epsilon_d}.$$

The five first terms of this expression are negative, and the sign of the last term is indeterminate. Not in all generality, but with a reasonable degree of confidence, we conclude that except in pathological cases, when $\phi = 1$ (and by continuity, when ϕ is large enough), the elite supplier produces more than a private supplier, but leaves some space for private suppliers.

(3) Going one step further, we consider the fraction $\nu = \mu_f^{AE}/M_f^{AE}$, equal to 1 when $n = 1$, and converging to 0 as competition increases (this implies that the optimal market share of the elite when n is very large converges to 0). Again, we assume a non-pathological situation where ν is a decreasing function of n. In that case, we find that dV_{AE}/dn is positive iff $n > \nu^{-1}((\phi + \lambda_{AE})/(1 + \lambda_{AE}))$. As a result, V_{AE} is a quasi-convex function of n.

APPENDIX H: NOTES ON THE GAIN FROM APPROPRIATION

In the corresponding section, we do not feel that we can write a formal general proposition with enough confidence, although many of the intuitions we discuss hold with the most common functional forms of the literature. To consider the effect of a feature of the innovation on the gain from appropriation, Equation (11) implies we need to consider how supply varies under appropriating and non-appropriating elites and how the integrand varies with the feature under consideration. As an illustration, let us consider the feature whose effect is most uncertain, that is, the ease of concealment, which we have characterized implicitly with H' and explicitly with α' (when the innovation becomes harder to conceal, α' and H' increase, in the partial order described above). To establish the result, for instance, that the gain from appropriation decreases with ease of concealment (holding constant other features of the innovation), it is sufficient to establish that the sign of $G''_{KM}\overline{K} + G''_{MM}m$ is negative over the range (M_f^E, M_f^{AE}), and that surplus supply is positive and increases; or that the sign of $G''_{KM}\overline{K} + G''_{MM}m$ is positive over the range (M_f^E, M_f^{AE}), and that surplus supply is negative and decreases. These conditions are each sufficient. Neither is necessary, but it seems difficult to write a more encompassing condition without imposing functional forms. Corollary 1 is inconclusive about the variation in surplus supply. Although we have shown above that the direct effect of concealment on surplus supply is positive, the indirect effect through its interaction with rivalry/IRS is unclear. As the last consideration, per Corollary 1, if $\phi \geq \phi_1, M_f^{AE} \geq M_f^E$. Therefore when $\phi > \phi_1$, for an innovation that displays IRS, the gain of appropriation decreases with ease of concealment. These promising considerations do not amount to any conclusive result.

Ease of concealment is inconclusive, but the same reasoning on mobility, complementarity, and general-purposeness yields the considerations developed in the main text. One specific note on complementarity: the program of the appropriating elite yields a larger (when $\phi \geq \phi_1$), and increasingly larger (when $\phi \geq \phi_2$), supply of an innovation whose complementarity increases. As a result, the gain of appropriation increases with complementarity when $\phi \geq \phi_2$. The result holds more generally. In particular, it holds whenever at 0, $\alpha' G''_{KM}\overline{K} \leq -\phi(G'_M - H)$ and whenever G''_{KM} is large enough to ensure that $M_f^{AE} \geq M_f^O$. However, for $\phi < \phi_2$, the range $M_f^{AE} - M_f^E$ is not increasing everywhere with complementarity. For $\phi < \phi_1$, there is even a subset of production functions on which supply under the non-appropriating elite would exceed supply under the appropriating elite, that is, $M_f^{AE} < M_f^E$, and on which the gain of appropriation would decrease with complementarity. In fact, for $\phi \leq \phi_1$, the effect of complementarity would be non-monotonic.